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# Environmental Effects of Dredging

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## Eagle Harbor Superfund Project

by

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**P**uget Sound's Eagle Harbor, a Superfund site, provided a unique opportunity for cooperation between the U.S. Army Corps of Engineers' maintenance dredging program and the U.S. Environmental Protection Agency (EPA).

During the fall and winter of 1993-1994, the Corps of Engineers used nearly 250,000 cubic meters (m<sup>3</sup>) of maintenance

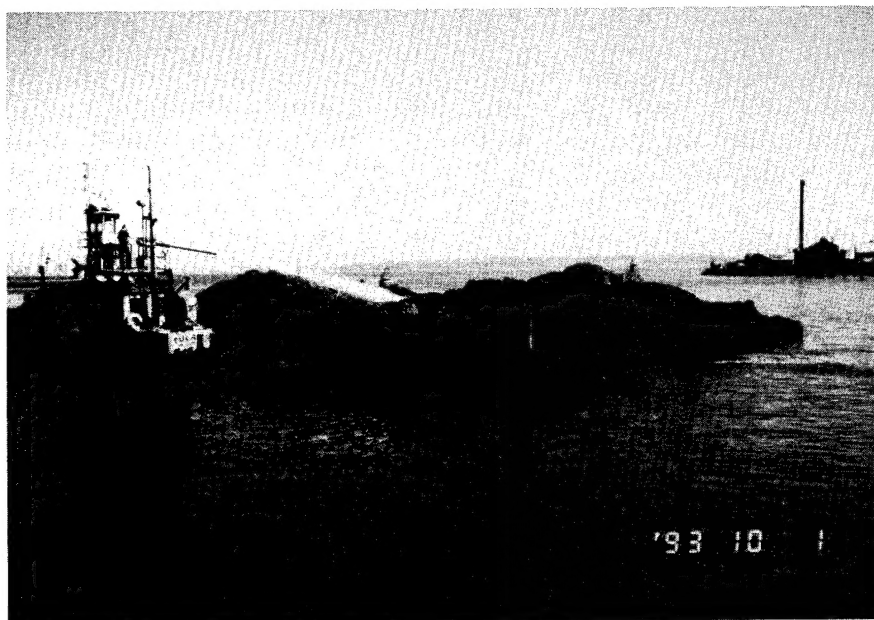
dredged material from the Snohomish River to cover approximately 217,000 square meters of creosote-contaminated sediments in Eagle Harbor, Washington.

The harbor, contaminated by chemicals seeping from a nearby wood treatment plant, was listed by the EPA as a Superfund site in 1987. Taking advantage of the available maintenance

dredged material offered EPA the opportunity to both initiate an early start on the cleanup process and to realize considerable cost savings.

At the request of the EPA, the U.S. Army Engineer District, Seattle, modified its maintenance dredging contract for the Snohomish River to include placing a 0.9-meter-thick layer of dredged material over the existing bottom sediments. Constraints not normally considered in typical maintenance dredging projects had to be addressed in the placement design. In particular, placement rates and locations had to be controlled to create a uniform layer of material over a large area without resuspending contaminated bottom sediments or interfering with the Washington State ferries that cross the site every 40 minutes.

Information and numerical models developed through the Corps' Dredging Research Program (DRP) were used to help produce a final design that could be accomplished with readily available dredging equipment.



This 40-year-old disposal method was combined with state-of-the-art technology to produce an effective and economical project

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## Background

In the early 1980s, scientists discovered that an inordinately high percentage of the fish caught in a small harbor on the western shore of Puget Sound had liver disease and tumors. By 1985, the EPA had determined that sediments in the eastern portion of Eagle Harbor were heavily contaminated with polynuclear aromatic hydrocarbons (PAHs). As a result, a health advisory recommending against eating shellfish caught in the harbor was issued. Metals, particularly mercury, were found to be a secondary contaminant in the western portion of the harbor. In 1987, the Harbor and the wood treatment facility were designated as a Superfund site by the EPA. Between 1987 and 1992, the EPA developed a number of alternatives for accomplishing the cleanup of Eagle Harbor.

Since the type of contamination present and the potential for recontamination in the western and eastern portions of the harbor were significantly different, the site was divided into East and West Operable Units. In the West Operable Unit, the proposed cleanup plan was to remove the mercury hot spot and to place a thin layer of clean sediment over the remaining contaminated sediment. Alternatives considered for the East Operable Unit included dredging the contaminated sediment and placing it in a confined aquatic disposal (CAD) site or a waste landfill, or treating it by incineration, solidification, or biological slurry.

The estimated cost of these alternatives ranged from \$21.3 million to \$273.6 million. However, the EPA's preferred alternative for the East Operable Unit was to leave the contaminated sediment in place and cap it with

clean material. The cost of this alternative was estimated at between \$14.1 million and \$23.8 million.

In May 1993, the EPA requested that the Corps of Engineers modify its upcoming maintenance dredging contract for the Snohomish River to include placing a portion of the sand in Eagle Harbor to create a uniform 0.9-meter-thick layer of sandy dredged material over approximately 220,000 square meters of contaminated sediments.

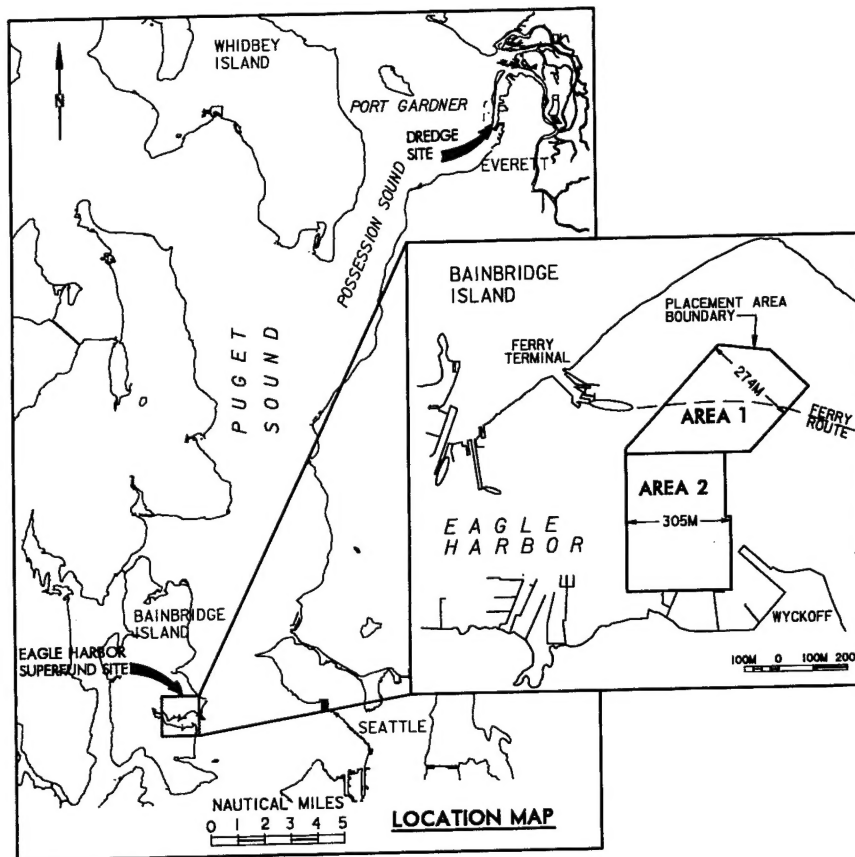
## Placement design

The narrow entrance channel and surrounding hills protect Eagle Harbor from all significant winds and waves. Except for the propeller wash of the ferries, most of the harbor is subject to slow (<10 centimeters/second) tidal currents. Water depth in the East Operable Unit varies from about 15 meters at the north end to 9 meters along the edges of the southern portion. While the protected, relatively shallow waters appeared to be ideal for placement operations, the design goal of constructing a uniform layer of dredged material, 0.9 meters thick, over the entire site was subject to a number of constraints that usually are not encountered in typical maintenance dredging projects in Puget Sound. The small harbor appeared to lack adequate maneuvering room for a tug and tow, particularly in the southern portion of the site. The ferry from Bainbridge Island to downtown Seattle departs every 40 minutes, and its route runs directly through the northern portion of the site. To complicate matters further, sediment core samples obtained by EPA divers indicated that the southern por-

tion of the placement area had particularly soft bottom sediments. Thus, the northern portion of the site required a placement method that was rapid enough to place material in the 40-minute interval between ferry trips, while the southern portion required a method that was slow enough to avoid resuspending contaminated sediments. Because of the apparent conflicting nature of these two requirements, different placement methods were specified for each area (Figure 1).

In the relatively unobstructed northern portion of the Harbor (Area 1), a standard placement procedure used at open-water disposal sites appeared to be the most efficient way to place the required amount of material in the short period of time available. In this procedure, a bottom-dump barge, towed or pushed by a tug, discharges its load while under way. However, without some controls, this placement method would have resulted in materials being deposited unevenly and at a rate that might have caused an unacceptable level of disturbance of existing sediments.

A placement plan was developed using numerical model results from previous work done by the Seattle District for the EPA in the Thin Layer Placement Feasibility Study (U.S. Army Engineer District, Seattle 1992). This study found that sand, placed by a single load from a 765-m<sup>3</sup> barge (assuming a placement rate of 8 m<sup>3</sup>/sec and a speed of 3 knots) would cover an area approximately 170 meters long and 45 meters wide to an average depth of 9 centimeters, with a maximum depth of approximately 15 centimeters. These results indicated that the rate of placement could be controlled by restricting the opening angle of



**Figure 1. Eagle Harbor Superfund site**

the barge, and placement of a relatively thin layer over a large area would be possible.

In the southern portion of the Harbor (Area 2), where bottom sediments were particularly soft, the goal was to spread material uniformly throughout the area with the least possible disruption of the contaminated bottom sediments. Discharging a sand-water slurry at the water surface and allowing sediment particles to fall to the bottom at their individual settling rates appeared to be the most appropriate means to accomplish this goal. Allowable methods of placement included pumping dredged material out of a barge hydraulically or washing it from the deck of a flat-deck barge with a high-pressure water jet.

Placement specifications stated that the objective of the project

was to place a uniform 0.9-meter-thick layer of dredged material within the two placement areas in a manner that minimized the displacement of existing contaminated bottom sediments. The development of specific placement methods was left to the prospective bidders. Dredging and placement were made separate bid items, so that the EPA was charged only for the cost of placement in Eagle Harbor. The bid schedule included items for mobilization and demobilization, dredging, placement in Eagle Harbor, and placement at the nearby Port Gardner open-water disposal site. The estimated volume to be dredged was 354,000 m<sup>3</sup>. Placement quantities for Eagle Harbor were estimated at 95,575 and 114,700 m<sup>3</sup> for Areas 1 and 2, respectively, with the remainder of the dredged material going to Port Gardner.

The specifications imposed minimal restrictions on the placement operations. In Area 1, the barge had to be moving at a minimum speed of 2 knots, and the placement rate could not exceed 3 m<sup>3</sup>/sec. In Area 2, the barge position had to be changed frequently enough to prevent creation of mounds greater than 0.9 meter high. A key requirement in both areas was that, at the completion of placement operations, barge paths had to be evenly distributed through the disposal site. The project retained the straightforward aspect of a maintenance dredging project with a slightly modified disposal procedure.

The contractor (American Construction of Everett, Washington) chose to use a 1,070-m<sup>3</sup> (net-line capacity) bottom-dump barge to place material in Area 1 and to wash sand from flat-deck barges with a high-pressure water jet in Area 2. The cost for placement was \$1.45 per cubic meter (\$1.11 per cubic yard) in Area 1 and \$3.17 per cubic meter (\$2.42 per cubic yard) in Area 2.

## Placement operations

Maintenance dredging of the Snohomish River began on September 15, 1993. Suitable material, after being dredged by clamshell, was loaded onto barges and towed 50 kilometers down Puget Sound to Eagle Harbor. Material that had too high a percentage of fine material was taken to the nearby open-water disposal site in Port Gardner. The material placed in Eagle Harbor was primarily silty sand with a low percentage of clay (in situ composition, by volume, was 0.9 percent gravel, 20.5 percent sand, 14.8 percent silt,

3.6 percent clay, and 60.2 percent water).

After successfully demonstrating that the disposal times of the bottom dump could be extended to as long as 40 minutes at the Port Gardner disposal site, the contractor began placing material in Area 1 (Figure 2). The average load was  $1,450 \text{ m}^3$ , and disposal times varied from 20 to 35 minutes. By shortening the towline length, the tug operator

was able to maneuver within the placement area, even when the area was being shared with a 134-meter-long ferry. Controlling the rate of placement from the bottom-dump barge required constant adjusting of the opening angle. An initial angle of several degrees allowed sand to be dispersed fairly uniformly. As material was eroded from the bottom of the load, the barge opening angle had to be increased to keep

material flowing from the barge. Occasionally, a portion of the load would "hang up" and then rapidly exit the barge in a large mass.

In Area 2, the material was washed from the flat-deck barges with a high-pressure water jet. The barges were secured together, and a smaller tug (equipped with a fire monitor) was tied alongside. As material was washed from the barges, a larger tug continuously moved the barge/tug combination to avoid excessive placement at one location. The contractor was able to place about  $1,150 \text{ m}^3$  ( $575 \text{ m}^3$  per barge) in 5 to 6 hours, for an average placement rate of about  $3.5 \text{ m}^3$  per minute (Figure 3). The method of placement for Area 2 was intended to disperse dredged material widely and slowly enough to allow a large portion of the sediment to settle through the water column at the individual particle settling rate, rather than in a convective descent. As was expected, short periods of elevated turbidity were measured near the bottom during the placement process, but dissolved oxygen levels remained at or above 5.5 milligrams per liter, well above the EPA's minimum water quality criterion.

The success of both placement methods was critically dependent on the ability to monitor and to record barge position. The position of the barge was determined using a differential global positioning satellite (GPS) system and displayed to the tug operator, in "real time," on a laptop computer located in the tug wheelhouse. The barge location was updated every 30 seconds, and a circle was plotted on the computer screen. As new locations were added, the tug operator was able to maneuver to



**Figure 2. Placement in Area 1 using a bottom-dump barge**



**Figure 3. Placement in Area 2 using a high-pressure water jet**



create a uniform coverage of the areas. Every minute, barge positions were recorded onboard the tug and, via radio link, at the District office. By plotting and connecting the positions on the District's computer-aided drafting and design system, barge track lines were created. As the track lines filled in the areas, the density of track lines was used to estimate areas that needed additional material or areas that were to be avoided because they had received excessive material (Figure 4).

## Physical monitoring

The extent and thickness of the accumulating material were monitored by a Corps contractor, Science Application International Corporation (SAIC). SAIC used five different monitoring methods—bathymetric surveys, settling plates, sediment vertical profiling system (SVPS), underwater video, and subbottom sonar profiler.

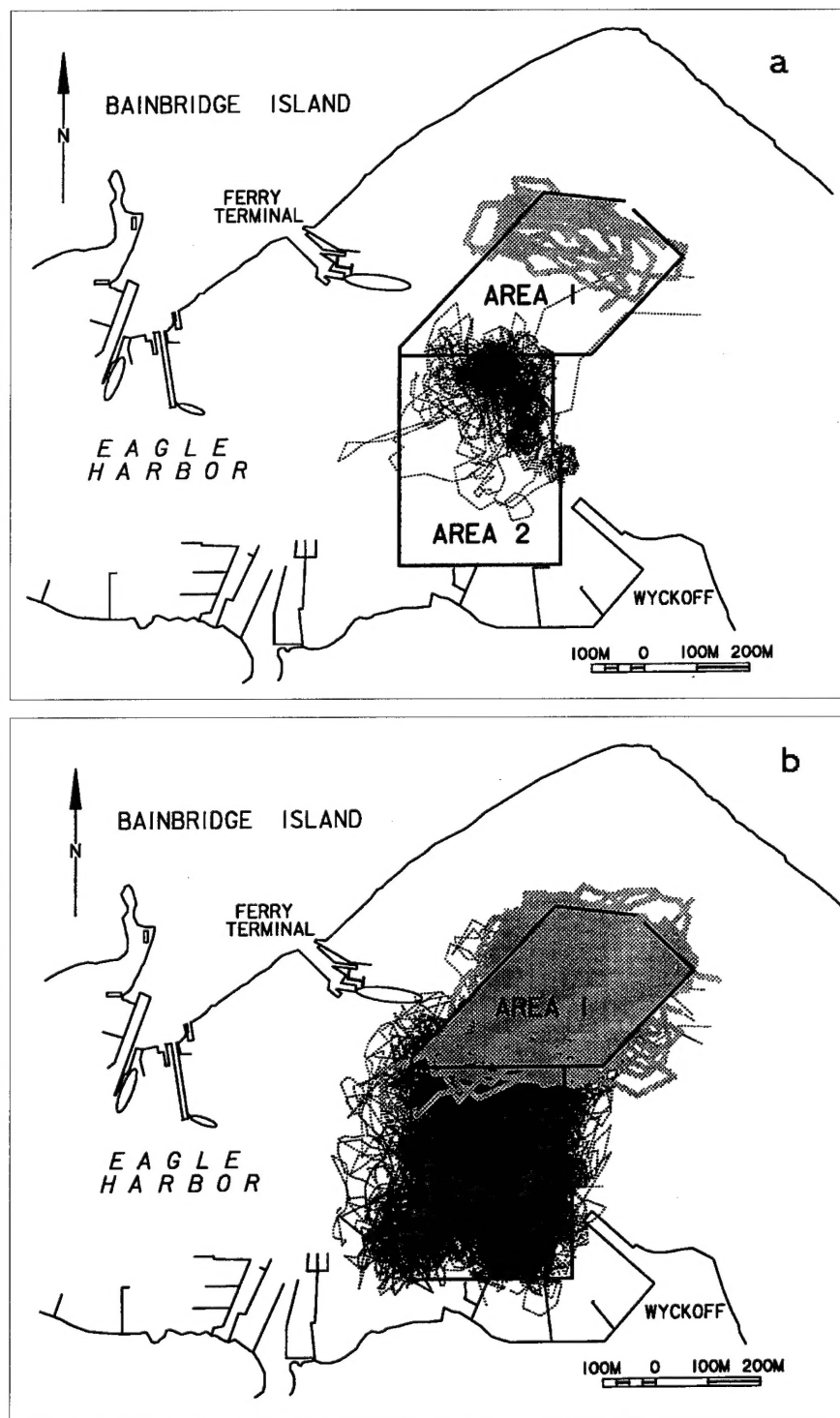
Bathymetric surveys were carried out to ensure that areas of excessive thickness did not accumulate, particularly in the ferry lane. Consecutive surveys were compared to estimate the thickness of the placed material. Surveys were spot-verified using a series of "settling plates" placed at six locations along the project center line. Each settling plate was constructed of a large and a small steel plate attached to either end of a 2-meter-long post. The posts were mounted vertically on the large (1.2 by 1.2 meter) bottom plate. The second, smaller plate (0.3 by 0.3 meter) was mounted on the top of the post.

Before construction was initiated, the device was lowered to the bottom. As sediment was

deposited on the bottom plate, sonar images obtained during bathymetric surveys showed a corresponding decrease in the distance between the top plate and the "new" bottom. In addition,

graduations on the posts were occasionally read directly by divers.

A SVPS was used to monitor the extent of newly placed material and to detect thin areas. The SVPS is a remotely operated



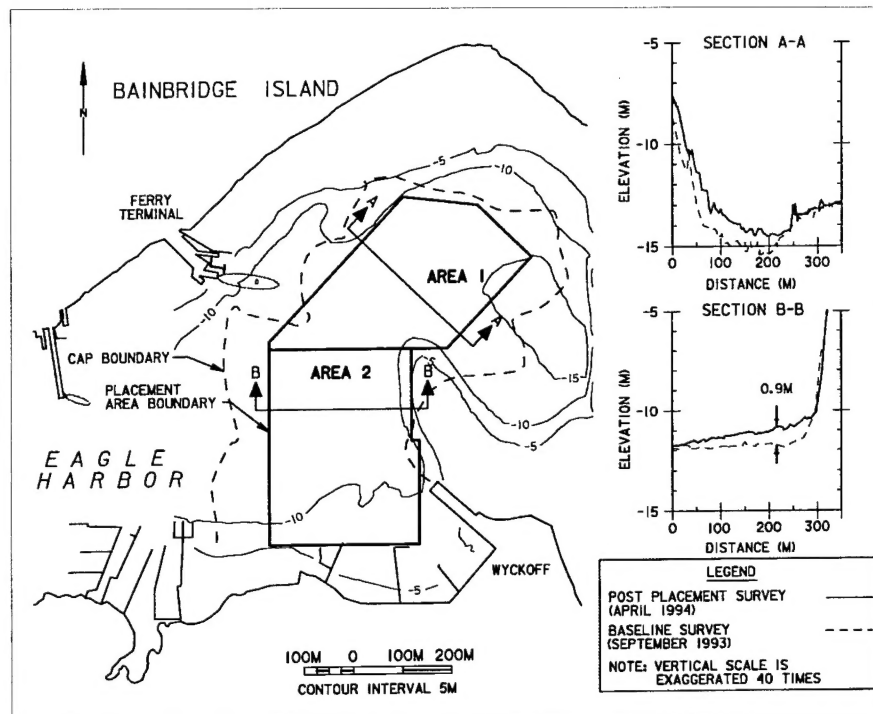
**Figure 4.** Barge track lines in Eagle Harbor (a) after 1 week of placement and (b) near completion of project

camera that drives a prism into the bottom and takes a photograph of a 20-cm-high cross section of the sediment-water interface. Areas that were found to have less than a 15-cm thickness of new material were noted as requiring additional coverage. Approximately two thirds of the way into the project, a towed video camera was used to ensure visually that the newly placed material was not being recontaminated by creosote seeping out of bottom sediments or by an unknown upland source. At the completion of construction, the bathymetric and SVPS measurements were confirmed by a sub-bottom sonar profiling system.

A comparison of pre- and post-bathymetric and SVPS measurements showed that a 0.3- to 0.9-m layer of dredged material had been placed over essentially all of the area of concern (Figure 5). A detailed description of the monitoring methods and the data that were obtained are presented in the "Statement of Findings" for the project (U.S. Army Engineer District, Seattle 1994).

## Results

The first phase of the EPA's remedial action plan for Eagle Harbor appears to have been completed successfully. Postconstruction surveys using the sub-bottom sonar profiler have confirmed that a layer of clean sediment was placed over the target area. The project was completed on schedule and for a cost well below that anticipated in the initial planning phase. In 178 days of construction, essentially all of the suitable dredged material that was available from the Snohomish River was placed over the creosote-contaminated sediments of Eagle Harbor. A total



**Figure 5. Comparison of pre- and postbathymetric surveys, Eagle Harbor**

of 67 trips were made with the bottom-dump barge to place 97,500 m<sup>3</sup> in Area 1. In Area 2, 99 trips were required with the flat-deck barges to place 107,000 m<sup>3</sup>. An additional 7,200 m<sup>3</sup> was placed in the most critical portion of Area 1 from the flat-deck barges. Only 8 days were lost because of weather (high winds). Placement at Eagle Harbor was suspended for an additional 10 working days to evaluate the effects of the newly placed material.

In Area 1, small "oil slicks" appeared occasionally during the placement operations. Initially, the southern portion of Area 1 (designated the "hot spot" by the EPA) was particularly sensitive to the rate of placement. When dredged material inadvertently left the bottom-dump barge in clumps (estimated at 4 to 40 m<sup>3</sup>), sheens or "daisies" of creosote-smelling material sometimes rose to the surface. In an effort to reduce the risk of resuspending contaminants, approximately

7,200 m<sup>3</sup> of dredged material was placed in the hot spot using the gentler (but much slower and more expensive) hydraulic placement method. This procedure appeared to work because the frequency of the slicks declined as the thickness of the placed material increased. The number and size of "clumps" leaving the bottom-dump barge increased as the placement of each load progressed. For this reason, an attempt was made to place the final portion of each load in the "less sensitive" northern part of Area 1. Bathymetric and subbottom profile surveys of this area found several mounds, some over 2 meters high, representing clumps as large as 150 m<sup>3</sup>. The presence of these mounds was confirmed by diver and video observations. However, since all of the mounds were located away from the heavily traveled portion of the harbor and since none of them extended above an elevation of -12 meters mean lower low water, they were not

considered to be a threat to navigation safety.

In Area 2, SVPS, underwater video, and diver observations indicated that the buildup of material was slow and uniform. The video coverage showed an abundance of marine life rapidly recolonizing the placement areas, sometimes as material was being placed. Numerous pieces of small wood debris, probably entrained during dredging and deposited along with the placed sediment, were scattered over the bottom. This debris is now

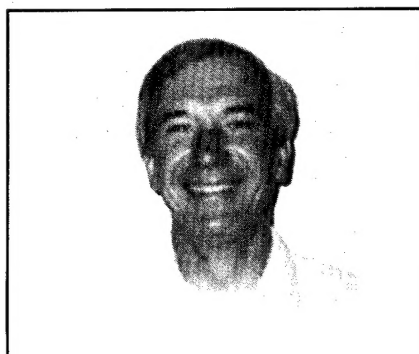
providing new habitat for numerous species of invertebrates.

Although the placement operations were successfully completed, extensive monitoring of the site is planned to determine if the newly placed layer of material can successfully isolate the underlying sediments that have contaminated this harbor for nearly 100 years.

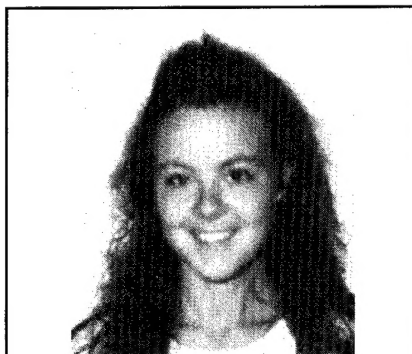
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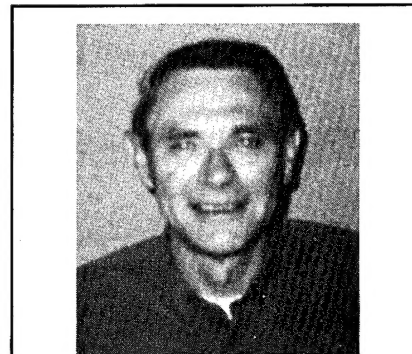
U.S. Army Engineer District, Seattle. 1994. "Statement of Findings, Removal Action; East Harbor Operable Unit of the Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Washington" (Draft), Seattle, WA.



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## Calendar of dredging-related events

- |                                |   |
|--------------------------------|---|
| November 14-17, 1995           | <b>Fourteenth World Dredging Congress; Dredging Benefits</b> , Amsterdam, The Netherlands, POC: CEDA Secretariat, P.O. Box 3168, 2601 DD Delft, The Netherlands, fax +31 (0)15-787104             |
| November 14-17, 1995           | <b>Dredged Material Testing, Assessment, and Management Seminar</b> , cosponsors: USEPA and USACE, Portland, Oregon, POCs: Larry Bird, (601) 634-4148, and Tom Patin, (601) 634-3444              |
| February 26 -<br>March 1, 1996 | <b>Corps of Engineers' Water Quality Seminar</b> , Committee on Water Quality, POC: Bob Gunkel, (601) 634-3722  |
| March 10-14, 1996              | <b>Sixth Federal Interagency Sedimentation Conference</b> , "Sedimentation Technologies for Management of Natural Resources in the 21st Century," Las Vegas, NV, POC: Bill Boning, (703) 648-5303 |



***Material from the Corps' maintenance dredging on the Snohomish River was used to cover contaminated sediments in Puget Sound's Eagle Harbor, offering the opportunity for the U.S. Environmental Protection Agency to get an early start on cleanup of this Superfund site and also realize considerable cost savings.***



## ENVIRONMENTAL EFFECTS OF DREDGING

This bulletin is published in accordance with AR 25-30 as an information dissemination function of the Environmental Laboratory of the Waterways Experiment Station. The publication is part of the technology transfer mission of the Dredging Operations Technical Support (DOTS) Program managed by the Environmental Effects of Dredging Programs. Results from ongoing research programs will be presented. Special emphasis will be placed on articles relating to application of research results or technology to specific project needs. Contributions of pertinent information are solicited from all sources and will be considered for publication. The contents of this bulletin are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or the approval of the use of such commercial products. Communications are welcomed and should be addressed to the Environmental Laboratory, ATTN: Dr. Robert M. Engler, U.S. Army Engineer Waterways Experiment Station (CEWES-EP-D), 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, or call AC 601/634-3624.

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